Damage class of Korean school building under design response spectrum level

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ABSTRACT: In the current seismic design provisions in Korea, school buildings are specified as refuge facilities after an earthquake. No investigations on existing school buildings, however, have been made to play a role as refuge facilities against future earthquakes. In this study, the damage class of existing school buildings in Korea is therefore analytically estimated. For this purpose, a 4-story frame including unreinforced concrete block walls based on the standard design of Korean school buildings in the 1980s is selected as a model structure, and six artificial ground motions corresponding to Korean design response spectrum level are used to analyze the seismic capacity.

Keywords*: Korean typical school building, damage class, design response spectrum, refuge facility, RC frame, unreinforced concrete block wall*

1. INTRODUCTION

In Korea, seismic design provisions for building structures first were introduced in 1988 and were revised in 2000 and 2005. Since the seismic design, however, was requested for the buildings more than six stories before 2005, school buildings which are mainly less than five stories have been excluded from the seismic design. In the current seismic design provisions in Korea, school buildings are specified as refuge facilities after an earthquake and are usually requested seismic design regardless of the number of stories. However, no investigations on existing school buildings in Korea have been made to play a role as refuge facilities against future earthquakes.

In this study, the seismic capacity and the damage class of existing typical school buildings in Korea, which should play a role as refuge facilities after an earthquake, are analytically estimated under Korean design response spectrum level. For this purpose, a 4-story frame including unreinforced concrete block (CB) walls based on the standard design of Korean school buildings in the 1980s is selected as a model structure, and six artificial ground motions corresponding to Korean design response spectrum level are used to analyze the seismic capacity.

2. DAMAGE CLASS OF EXISTING TYPICAL SCHOOL BUILDING IN KOREA

2.1 Outline of model structure

Figure 1 shows a standard design of Korean school buildings in the 1980s (The Ministry of Construction and Transportation (2002)). In this paper, the 4-story frame including CB walls of transverse direction are analytically investigated shown in the same figure. The average shear stress τ_b of the CB wall refers to the test results previously performed. In the tests, 2 specimens representing a first or fourth story of 4-story RC school buildings are investigated as shown in Figure 1. They are an infilled wall type 1 (IW1) assuming the first story and an infilled wall type 2 (IW4) assuming the fourth story. Figure 2 shows the relation between the lateral load and the drift angle of each specimen.

Assuming the discrepancy between the observed peak load of overall frame and the calculated shear strength of only both columns is carried by the CB wall, the average shear stresses τ_B of both specimens are approximately $0.4N/mm^2$. The response of the specimens including crack patterns and their mechanism is discussed by Nakano and Choi (2005).

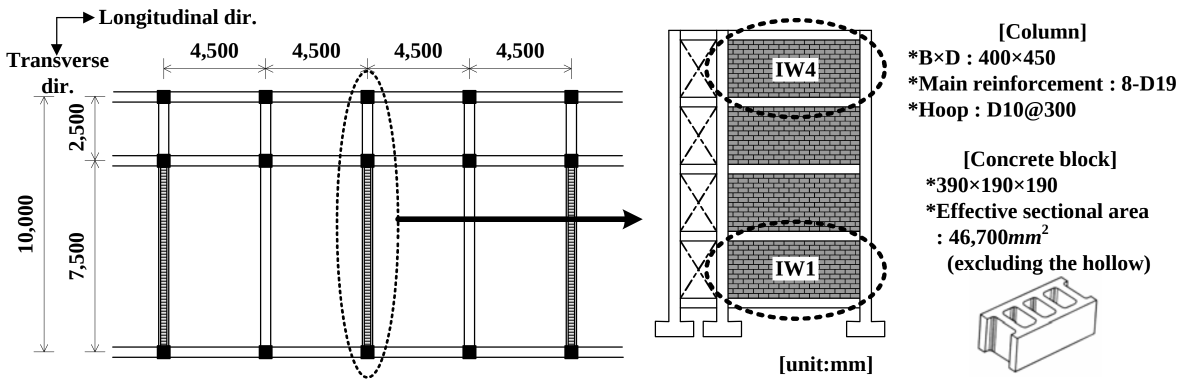

Figure 1. Standard design of Korean school buildings in the 1980s and model structure

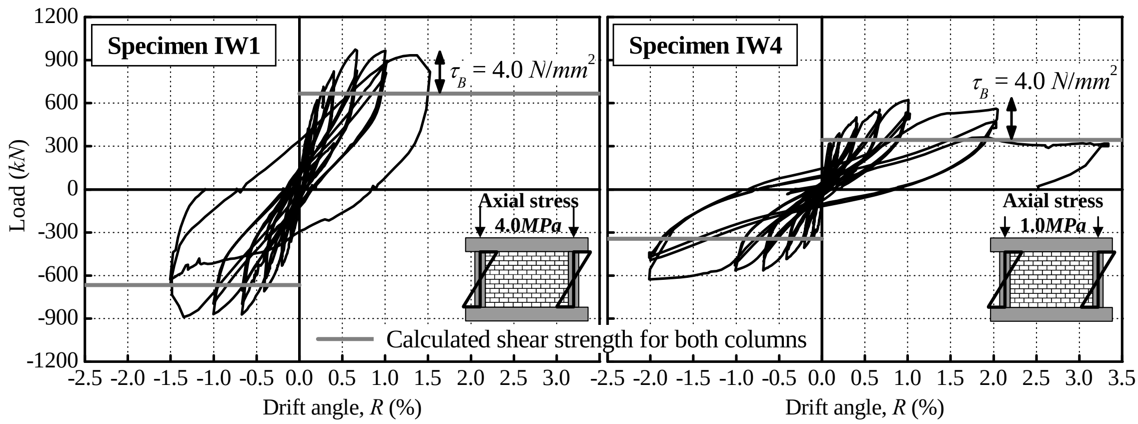

Figure 2. Load vs. drift angle of each specimen and average shear stress of CB wall

2.2 Hysteretic characteristics of model structure

To simulate the inelastic behaviors of the model structure, the load-deformation curve is represented with a simplified hysteretic model with assumptions (1) through (3) described below. Figure 3 shows the load-deformation relation of first story together with damage class determined by definition for RC members in the Guidelines for Post-Earthquake Damage Evaluation and Rehabilitation of RC Buildings in Japan (2001) as shown in Figure 4.

(1) The Takeda model is employed for the basic hysteretic rule assuming (a) no hardening in post-yielding stiffness and (b) stiffness degradation factor α of 0.7 derived from the test results during unloading.

(2) The yield load Q_y is calculated as the sum of shear strengths of three columns and one CB wall, and all of the average shear stress τ_B of the CB walls for each story are assumed $0.4N/mm^2$ from test results described above. The yield drift angle R_y is assumed 0.67% based on test results. The load Q_{cr} and drift angel R_{cr} at cracking point are assumed $Q_y/3$ and $R_y/15$, respectively.

(3) Since the ultimate ductility factors μ of specimens IW1 and IW4 as shown in Figure 2 are approximately 2.0 and 3.0, the factors μ of first story through forth story are assumed 2.0, 2.5, 2.5 and 3.0, respectively.

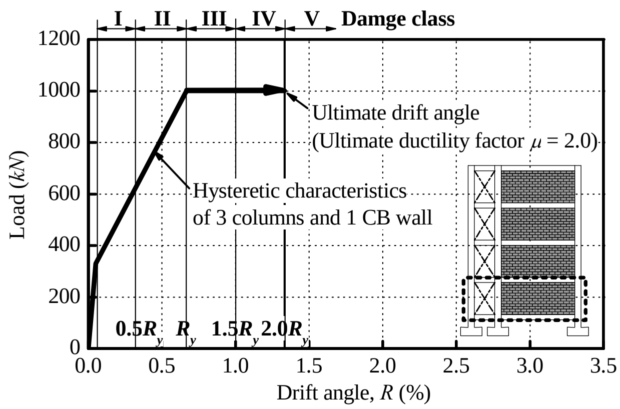

Figure 3. Load-deformation relation of first story

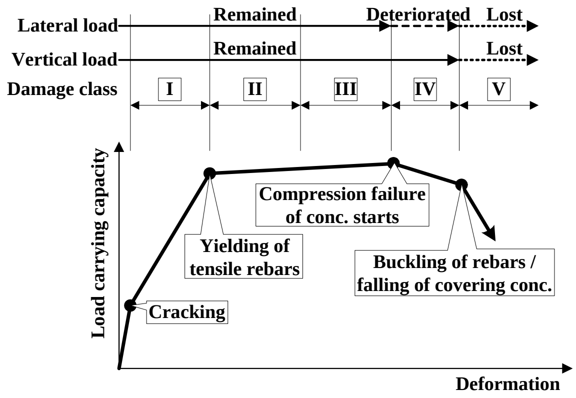

Figure 4. Schematic illustration of damage class (Ductile)

2.3 Ground motion data

Since the earthquakes of maximum acceleration level according to Korean seismic design provisions have not been occurred, six artificial ground motions herein are used to analyze the seismic capacity. A target elastic spectrum with 5% of critical damping S_A (T, 0.05) is then determined by equation (1),

$$S_A(T,005) = \begin{cases} 0.18 + 2.64T & & T < 0.1\text{sec} \\ 0.44 & cm/\text{sec}^2 & 0.1\text{sec} \le T < 0.52\,\text{sec} \\ 0.23/T & & T \ge 0.52\,\text{sec} \end{cases} \tag{1}$$

where T is the natural period of the SDOF model. The following 6 records are used to determine phase angles of ground motions: the NS component of El Centro 1940 record (ELC), NS component of Kobe 1995 record (KOB), EW component of Hachinohe 1968 record (HAC), NS component of Tohoku University 1978 record (TOH), NS component of Uljin 2004 record (ULJ) which has the highest maximum acceleration level among the earthquake data measured by Korean meteorological office, and random excitation (RAN). Table 1 shows the maximum acceleration of artificial ground motions and Figure 5 shows the elastic acceleration response spectra of artificial ground motions with 5% of critical damping.

Table 1. Input ground motion

Ground Motion record ID	Maximum ground acceleration (cm/sec^2)
ELC	341.7
KOB	-821.0
HAC	183.0
TOH	258.0
ULJ	72.5
RAN	-

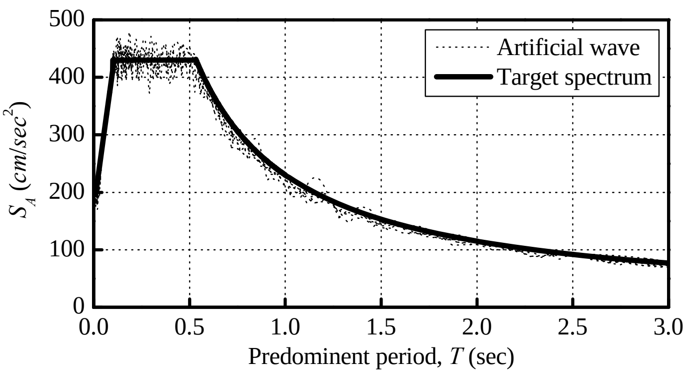

Figure 5. Elastic acceleration spectra

2.4 Damage class estimation of existing typical school building in Korea

In this section, the seismic capacity and the damage class of existing typical school buildings in Korea, which should be properly functional as refuge facilities as well as structurally safe after an earthquake, are analytically investigated using the hysteretic characteristics and 6 artificial ground motions mentioned in previous sections.

Figure 6 shows the inelastic behaviors of first story, where the serious damage is often found, for 6 artificial ground motions together with the damage class. As shown in this figure, the behaviors and damage classes are different due to phase angles of each ground motion. However, all of results exceed the yielding point, and the results of KOB, HAC and RAN particularly exceed the ultimate drift angle of 1.35% and reach in the state of damage class V (i.e., collapse). This result means that existing typical school buildings in Korea can not escape more than moderate damage and also do not play a role as refuge facilities against the earthquake of Korean design acceleration level.

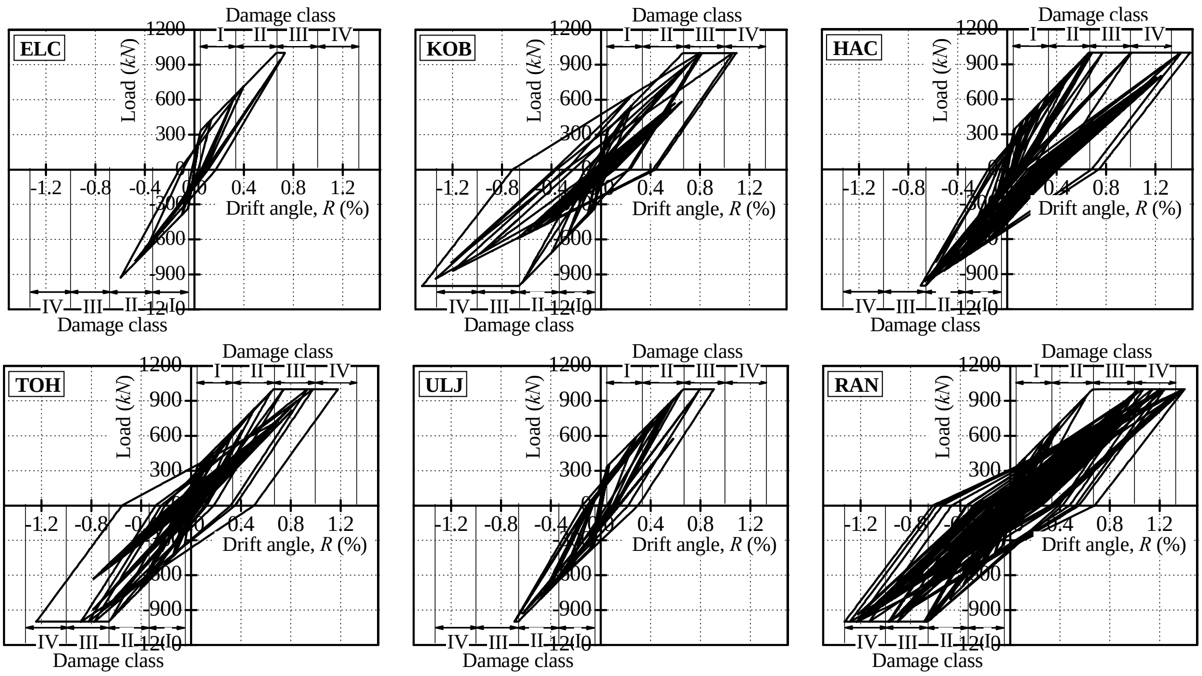

Figure 6. Inelastic behaviors and damage classes of first story

3. CONCLUSIONS

The seismic capacity and the damage class of Korean school buildings, which should play a role as refuge facilities after an earthquake, are analytically estimated under Korean design response spectrum level based on the test results. The damage classes of first story for 6 artificial ground motions exceed the yielding point, and the results of KOB, HAC and RAN particularly exceed the ultimate drift angle and reach in the state of damage class V. It is revealed that Korean typical school buildings can not escape more than moderate damage and also do not play a role as refuge facilities against the earthquake of Korean design acceleration level.

REFERENCES

JBDPA (The Japan Building Disaster Prevention Association). 2001. Guidelines for Post-Earthquake Damage Evaluation and Rehabilitation.

Nakano, Y. and Choi, H. 2005. Experimental Study on Seismic Behavior and Crack Pattern of Concrete Block Infilled RC Frames. New Technologies for Urban Safety of Mega Cities in Asia. Singapore.

The Ministry of Construction and Transportation. 2002. A Study on the Seismic Evaluation and Retrofit of Low-Rise RC Buildings in Korea: pp.113-155